Observational Constraints on the Rotational Dynamics of Mars

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A variety of observations provide constraints on the orbital and rotational motions of Mars and its satellites. In preparation for analysis of data from several up-coming spacecraft missions to Mars, which will provide important additional observations, we have been compiling and analyzing a large collection of rather disparate data, some of which extend back to 1877. This report summarizes the types of data, the uses to which they may be put, and reviews some of the results of our reanalysis of archival data.

One of the primary objectives of our analysis is to better constrain the rate of precession of the spin axis of Mars, since that will provide a better estimate of the moment of inertia of Mars [1,2]. The earliest observations relevant to that objective are the astrometric observations of the natural satellites Phobos and Deimos. These data have been collected at each opposition since the discovery of the natural satellites in 1877, and extend to the present, including recent HST observations of Phobos.. A shorter duration series of observations which also provides constraints on the motion of Mars includes the range and range-rate data for the Mariner 9 Orbiter and the Viking Orbiters and Landers. The motions of the landers obviously reflect motion of Mars, since they are firmly attached to its surface. The connection between Mars and its retinue of satellites is via the gravitational field. Present models of the gravitational field of Mars [3,4] are sufficiently accurate that the motions of satellites can be used to monitor the rotational motions of Mars.

The observations of artificial satellites are much more accurate than the observations of the natural satellites, but the natural satellite observational time series is much longer. In principle, a combination solution should capitalize on the strengths of both data types. However, until recently, the theoretical strength of combined solutions could not be attained, since there were no observations in the combined data set which directly linked the positions of the natural satellites to fixed locations on the surface of Mars with sufficient accuracy.

As a partial remedy to that problem, we have recently begun analysis of two Viking Lander data sets. The first consists of light curves of three eclipses of the Viking Lander II by Phobos on 20-27 September 1977. The second consists of direct images of Phobos that were taking during the night to estimate atmospheric dust loading.

Our expectation is that when these older data sets are combined with the tracking data from the Pathfinder and Mars Global Surveyor missions, they will significantly improve our ability to resolve secular and periodic terms in the rotational motions of Mars and will also improve knowledge of the orbital motions of Phobos and Deimos.

As an example of the utility of combination solutions, we present estimates of the rotational parameters of Mars based on three different data sets: Viking lander tracking data, Mariner 9 and Viking Orbiter tracking data, and a combination of the two. The table compares these solutions. There are several features of note. The lander-only solution has formal uncertainties which are 40-240 times smaller than the orbiter-only solution. Though the combination solution is dominated by the Viking Lander data, both the uncertainties and some of the parameter correlations are improved by the presence of the Orbiter data. The changes in the parameter estimates between the lander-only and combination solutions is consistently 20-40% of the formal uncertainty.

References

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2. Folkner, W.M., et al., J. Geophys. Res., (in press).
3. Smith, D.E., et al., J. Geophys. Res., 98, 20,871, 1993
4. Konopliv, A.S. and W.L. Sjogren, JPL Publ. 95-5, 1995.

Parameter	units	nominal	Lander change	sigma	Orbiter change	sigma	Both change	sigma
pole RA	m-deg	317681.00	-59.78	0.30	58.15	17.88	-59.66	0.30
pole Dec	m-deg	52,886.00	-27.67	0.33	-86.82	22.58	-27.74	0.32
RA rate	arcsec/yr	-3.888	-8.576	0.054	6.660	2.290	-8.555	0.053
Dec rate	arcsec/yr	-2.196	-3.860	0.057	-11.593	3.050	-3.870	0.057
prime meridian	m-deg	1422.01	0.72	0.10	-45.08	22.58	0.74	0.10
rotation period	m-sec	88,642,663.636	-0.031	0.003	-1.030	0.574	-0.032	0.003